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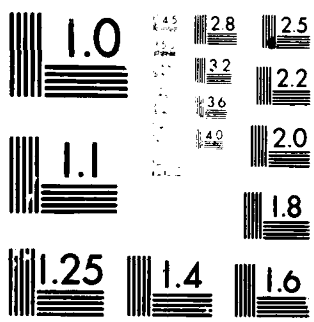

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ELECTRONIC PROCESSES IN InP AND RELATED COMPOUNDS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An experimental system to measure ionization coefficients in InP and related compounds is described. The current-voltage characteristics of Schottky barriers on p-type InP are presented. A set of masks designed to fabricate guarded Schottky diodes for making ionization coefficient measurements is described.

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1. INTRODUCTION AND SUMMARY

The major purposes of this research program are to study the electronic processes in InP and related compounds, to develop device structures suitable for making photocurrent measurements, and to analyze the bias dependence of the photocurrent to obtain the ionization coefficients of electrons and holes in these materials. Such measurements will be useful in the optimal design of avalanche photodiodes for optical communcations systems.

During this reporting period, the experimental equipment for photoresponse measurements has been assembled. Schottky-barrier devices were fabricated on lightly doped p-type bulk InP single crystals and their current-voltage characteristics studied. A new set of masks for fabricating guarded Schottky diodes has been designed and will be available for use on this program in early April. Experiments to control the doping level and surface morphology in liquid phase epitaxial (LPE) growth are in progress.

2. IONIZATION COEFFICIENT MEASUREMENTS

The noise and gain-bandwidth product limitations of avalanche photodiodes are strongly dependent on the ionization coefficients of electrons (α) and holes (β) in the material. These coefficients are obtained from a study of photocurrents. To obtain this information, it is necessary to achieve photomultiplied currents from pure electron and pure hole injection into the high-field region of the device structure. In addition, the electric field variation in the avalanche region must be known accurately.

In our experimental system, we will accomplish the pure electron and pure hole injection by the absorption of either 0.638 μm or 1.152 μm radiation. Two stable He-Ne lasers, one capable of operation at 0.638 μm and the other at 1.152 μm provide the necessary illumination. Chopped light from the two lasers is focused onto optical fibers, labeled 1 and 2 in Figure 1. The two fibers are fused together in the

middle, allowing coupling of radiation between the fibers. Approximately 50% of the radiation couples from fiber 1 to fiber 2 and vice versa. Radiation from fiber 2 is focused by a microscope objective onto the device structure, as shown in Figure 1. The radiation from fiber 1 is detected by a reference photodetector and provides a measure of the laser intensity incident on the test device at any given time. This feature will allow us to account for any fluctuations in the laser intensity during the time it takes to complete the measurement. The photo-induced currents will be measured by a current-sensitive preamplifier and a lock-in amplifier. The voltage applied to the device under test and the measurements will be controlled by a HP 9825A calculator. The system including the interface between the calculator and the lock-in amplifier has been assembled. The software necessary to perform the measurements is being developed.

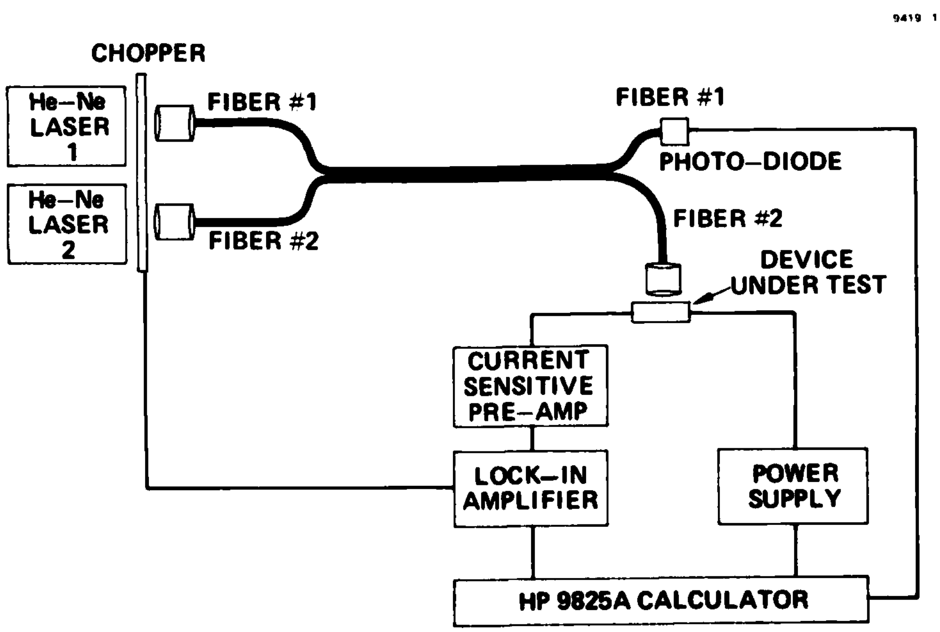

Figure 1. Schematic of ionization coefficient measurement system.

3. DEVICE STRUCTURES

During this quarter, we have fabricated Schottky-barrier devices in lightly doped p-type InP. The p-type InP crystals were obtained from Varian Associates and have carrier concentrations of $\sim 6 \times 10^{15}$ cm^{-3}. Ohmic contact to this material was formed by sputtering Au-Zn alloy onto the backside of the wafer and alloying it at 340°C for $\sim$5 min in forming gas ambient. The Schottky barriers were formed by evaporating Al onto the front side of the wafers. Typical I-V characteristics of such diodes in the dark are shown in Figure 2. The reverse leakage currents in these diodes were quite low ($\sim 1 \times 10^{-10}$ A at 30 V). There is considerable uncertainty concerning the voltage drop across the Schottky diode in the dark because of the excessively high series resistance associated with the lightly doped p-type material. Figure 3 shows the I-V curve in the presence of illumination, which substantially increases the conductivity of the material surrounding the diode. The leakage current is still low with breakdown voltages in excess of $\sim$20 V. The breakdown is quite sharp, and there appears to be no problem associated with microplasmas. To avoid surface leakage and series resistance problems, we have designed a new mask set which will allow us to fabricate guarded Schottky diodes. Using these masks, we will fabricate devices having both the Schottky diodes and the Ohmic contacts on the front side. Photocurrent measurements will be made by illuminating the (suitably thinned) sample from the back side.

Figure 4 shows the first level of masking which allows the Ohmic contact to be made. The Schottky diode and the guard ring metalization will be produced in a single photolithographic step (Figure 5). Two separate spacings (10 μm and 3 μm) between the guard ring and the Schottky contact are available. A set of unguarded devices can also be fabricated. Diodes with diameters of $\sim$50 μm, $\sim$100 μm, $\sim$200 μm, and $\sim$400 μm can be fabricated. This will allow us to evaluate the photoresponse of diodes with different diameters and also allow us to study leakage current mechanisms in these structures.

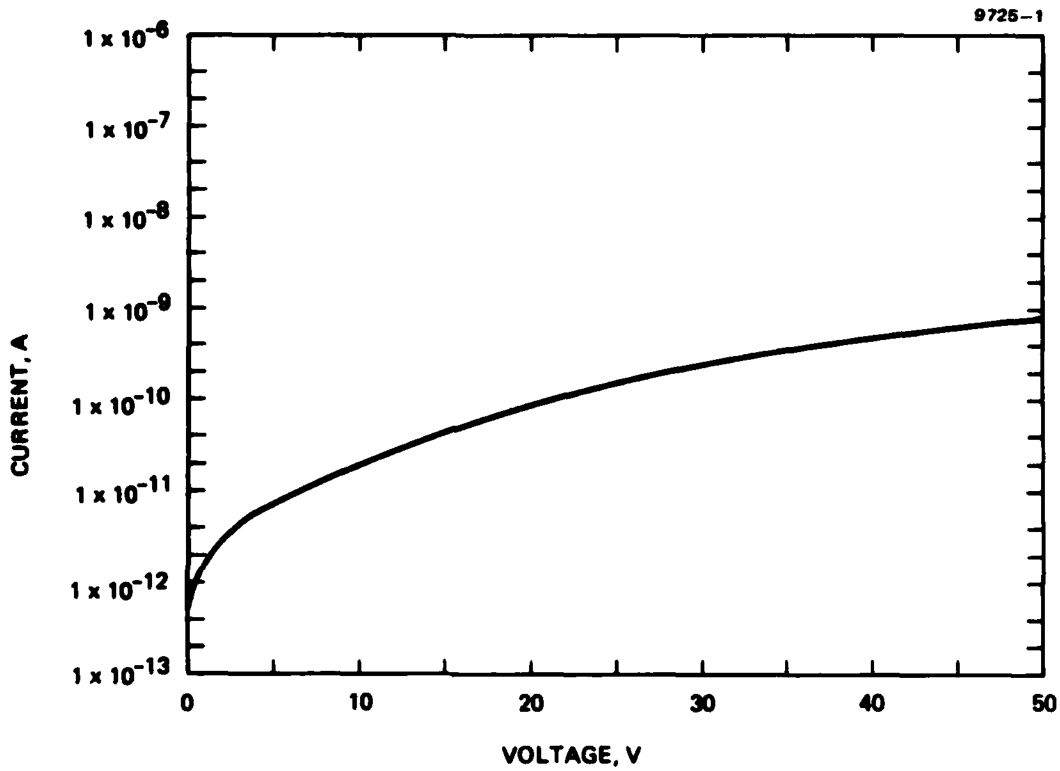

Figure 2. Current-voltage characteristic of Schottky diodes fabricated on p-InP in the dark.

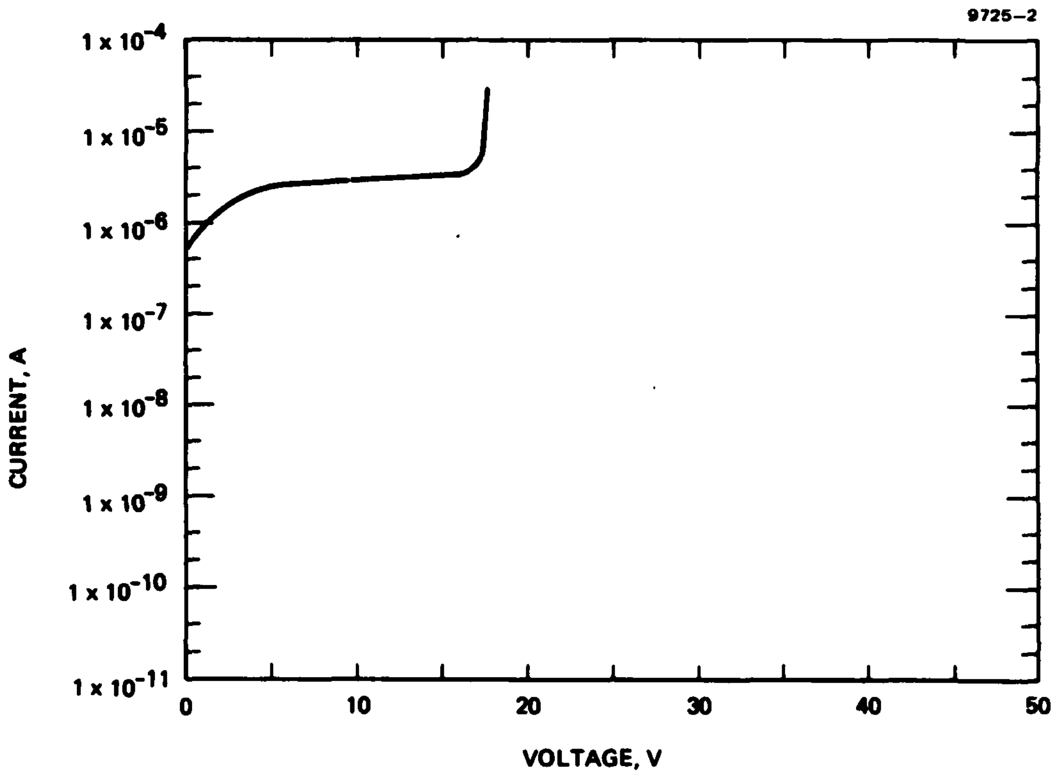

Figure 3. Current-voltage characteristic of Schottky diodes on p-InP. The diode was illuminated by a tungsten lamp.

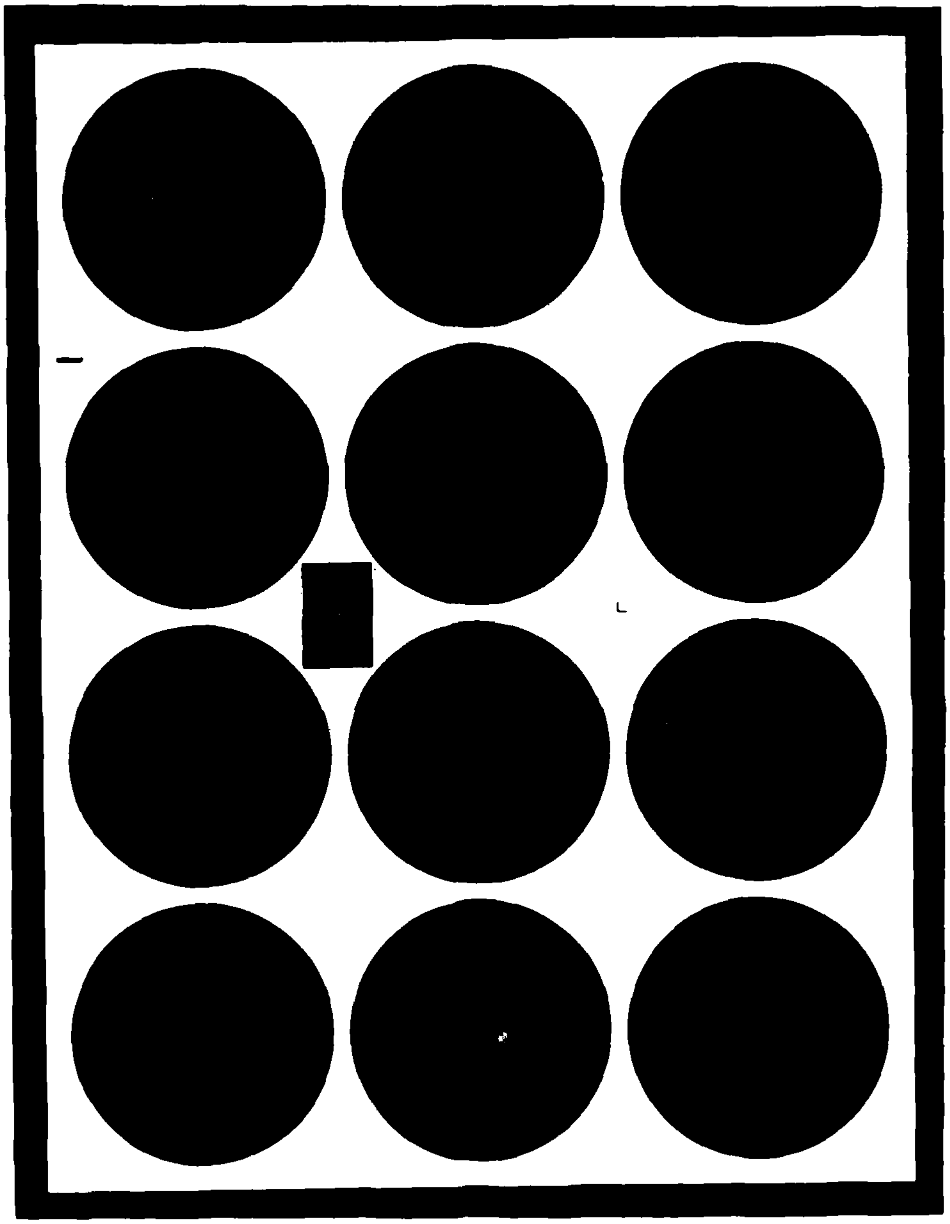

Figure 4. First level mask to define Ohmic contacts for fabricating guarded Schottky diodes in InP.

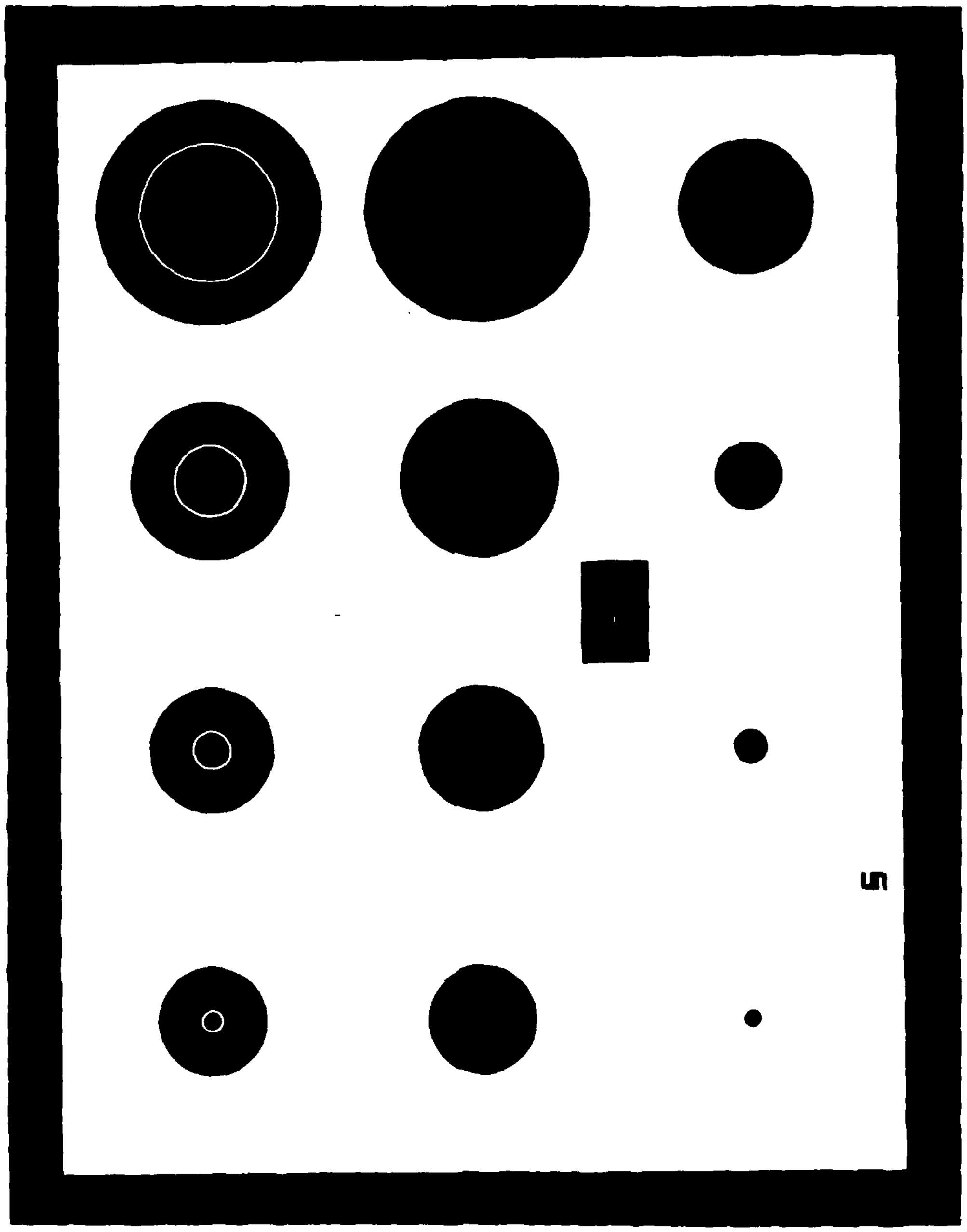

Figure 5. Second level mask to define the Schottky and guard ring in InP.

4. LIQUID PHASE EPITAXY OF InP

During this quarter, we have continued the growth of both high-purity and heavily doped (n^+) InP epitaxial layers, paying particular attention to morphological control. We have demonstrated that control of growth ambient using a proprietary growth process results in a reduction in carrier concentration by 10^2 in the layers grown from several solutions. More recent results suggest that not all solutions respond in the same fashion. More experiments are underway.

5. PLANS FOR NEXT QUARTER

In liquid phase epitaxial growth, we will investigate the growth of lightly doped p-type layers by controlled addition of Be to high-purity n-type solution. We will measure the photo-multiplied currents in guarded and unguarded Schottky diodes as a function of reverse bias and analyze the data to obtain the ionization coefficients $\alpha(E)$ and $\beta(E)$.

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